Space Weather Technical Forecast

Issued on Monday, 08 January 2024 at 00:55 Local

This technical forecast provides a four-day assessment of space weather events. The probabilities stated below are for reaching or exceeding the given levels. For more information about space weather impacts please see the Met Office Space Weather Scales https://www.metoffice.gov.uk/weather/learn-about/space-weather/uk-scales

Space Weather Forecast Headline: R1 becoming Likely. Now reduced and falling Slight Chance of G1 and S1.

Analysis of Space Weather Activity over past 24 hours

Solar Activity: Solar activity, as measured by GOES16 was Low, with frequent low to mid-ranking C-class flares, with a C6.3 at 07/0756UTC from AR3536 east of centre-disc trumped by a 07/2225UTC C8.7 from the departing AR3534. There were up to nine sunspot regions on the facing side, with AR3534 becoming indistinct on the southwestern limb, as AR3544 and AR3543 both attained numbers.

Sunspot region AR3536 was one of the more noteworthy magnetically, with an east-west orientated magnetic neutral line and a period of emergence of minor spots and pores forming first a ring-shaped structure and then a sigmoid shape, before finally consolidating into a main penumbral leader as the group spread. Another region of note was AR3540 in the southeast, which although peaking at Dki/Beta-Gamma complexity, later simplified and became marginally more open-centred as a Dhi/Beta-Gamma by the period's end. Perhaps the strongest growth trend was seen in newly-numbered AR3543 in the south central disc, which saw a period of strong spot development and later a spreading and areally increasing trend as a Dai/Beta. Rounding out developments, AR3539 saw growth of a new leading spot, and finally AR3538 in the northwest - although diffuse - saw a candidate for a possible weak Mt Wilson delta spot amongst its number.

The UTC weekend saw several minor coronal dimmings from the closely-knit central and northwestern disc clusters of sunspot regions. None have been definitively linked to Earth-directed CMEs, but this assertion is lower confidence than is typical given their small stature and frequency.

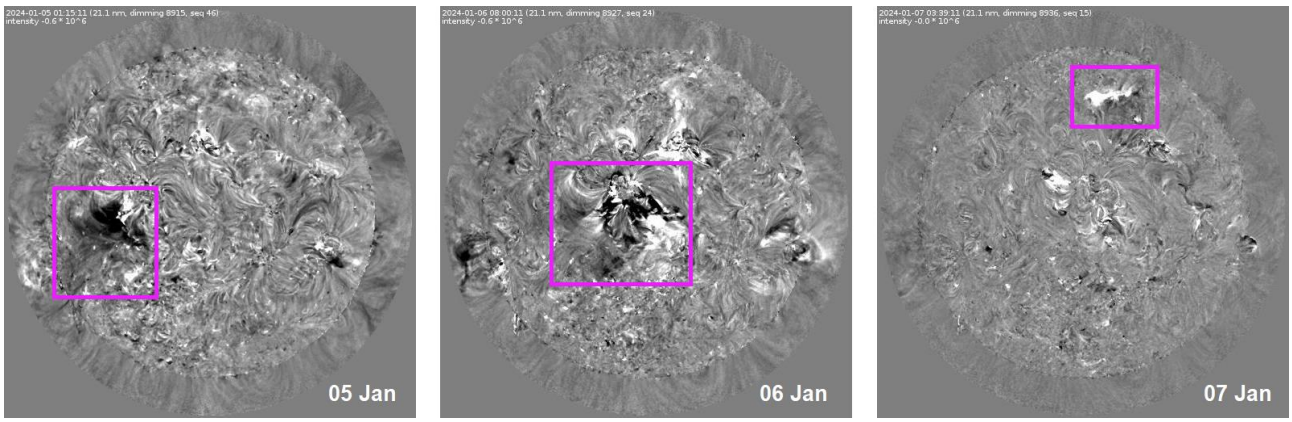

Figure 0: Main recent CME candidates. The left and central CMEs have slight Earth-bound components, due to pass 1AU later in the current UTC day and around the turn of the UTC day 09 into 10 January respectively. The third CME is a modelled close miss passing 1AU during the UTC day of 10 January.

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A filament eruption was observed leaving the northwest disc around 07/0320UTC on AIA304, with a centroid very approximately near N30W010. This has been associated with faint ejecta on Lasco C2 and STEREO COR2 seen heading mainly north and slightly west of the Sun-Earth line. MOSWOC Enlil modelling takes this CME past 1AU in the UTC day of 10 January - missing Earth to the north and west. A second event associated with activity near the middle of the disc and a filament immediately trailing AR3536 occurred around 07/1215UTC, with possible ejecta released. This could not be linked with any subsequent events on coronagraph imagery, and although still under assessment, it is now considered to have perhaps not left the immediate solar environment and been reabsorbed. Similar activity was observed in a filament trailing AR3538 through the UTC afternoon, and although buffeted by minor flares, no interplanetary CMEs could be definitively linked to disturbances here.

Solar Wind / Geomagnetic Activity: Solar winds, as measured at L1 by ACE and DSCOVR, continued to show marked discrepancies. ACE is preferred overall, but has limited reporting windows at present. The character of the wind overall was a slow regime, with a possible SSBC occurring around 07/1800UTC as both satellites registered a change in phi from negative to positive (the latter away from the Sun).

The solar wind speed showed a level tendency at Background levels, most likely in the low-300s of km/s. This was associated with Background solar wind density in single-figures ppcc and a steady and small-scale IMF at or below 3nT. The north-south component ranged between +/-2nT.

The net result of the above solar wind measures was provisionally Quiet geomagnetic activity throughout.

Energetic Particles / Solar Radiation: GOES18 high energy (greater than 10MeV) proton flux continued its slow decline of recent days towards resting Background levels in falling from around 2pfu to below 1 (where S1 is 10pfu).

GOES16 high energy (greater than 2MeV) electron flux was at Normal Background levels. The 24-hour fluence was below Active throughout, with a slightly rising trend. The 08/0001UTC observation was 3.44e6 integrated pfu.

Four-Day Space Weather Forecast Summary

Solar Activity: The risk of M-class flares rises slightly to become Likely in the period, with a continuing slight chance of X-class

Solar Wind / Geomagnetic Activity: Up to two CMEs feature at present and one fast wind regime. The most likely course of events is for the overdue fast wind to arrive within the first 24 hours, possibly now with the northeast quadrant CME from 05 January. The second east-central CME from 06 January may then follow after another 24 hours - with decreased likelihood and impact.

The net result is a falling Slight Chance of G1 through the first half of the UTC working week - most reliably Quiet at the end of the four-day period (barring new CMEs).

Energetic Particles / Solar Radiation: In the absence of further proton-rich flares in prone locations, levels may be allowed to relax back to resting background before the middle of the coming UTC working week, with a daily Slight Chance relaxing back to a residual risk by midweek after last week's enhancements.

High-energy electrons at GEO are expected to remain at Normal Background levels in the near-term, with a rising Slight Chance of Active 24-hour integrated fluence before midweek UTC in the

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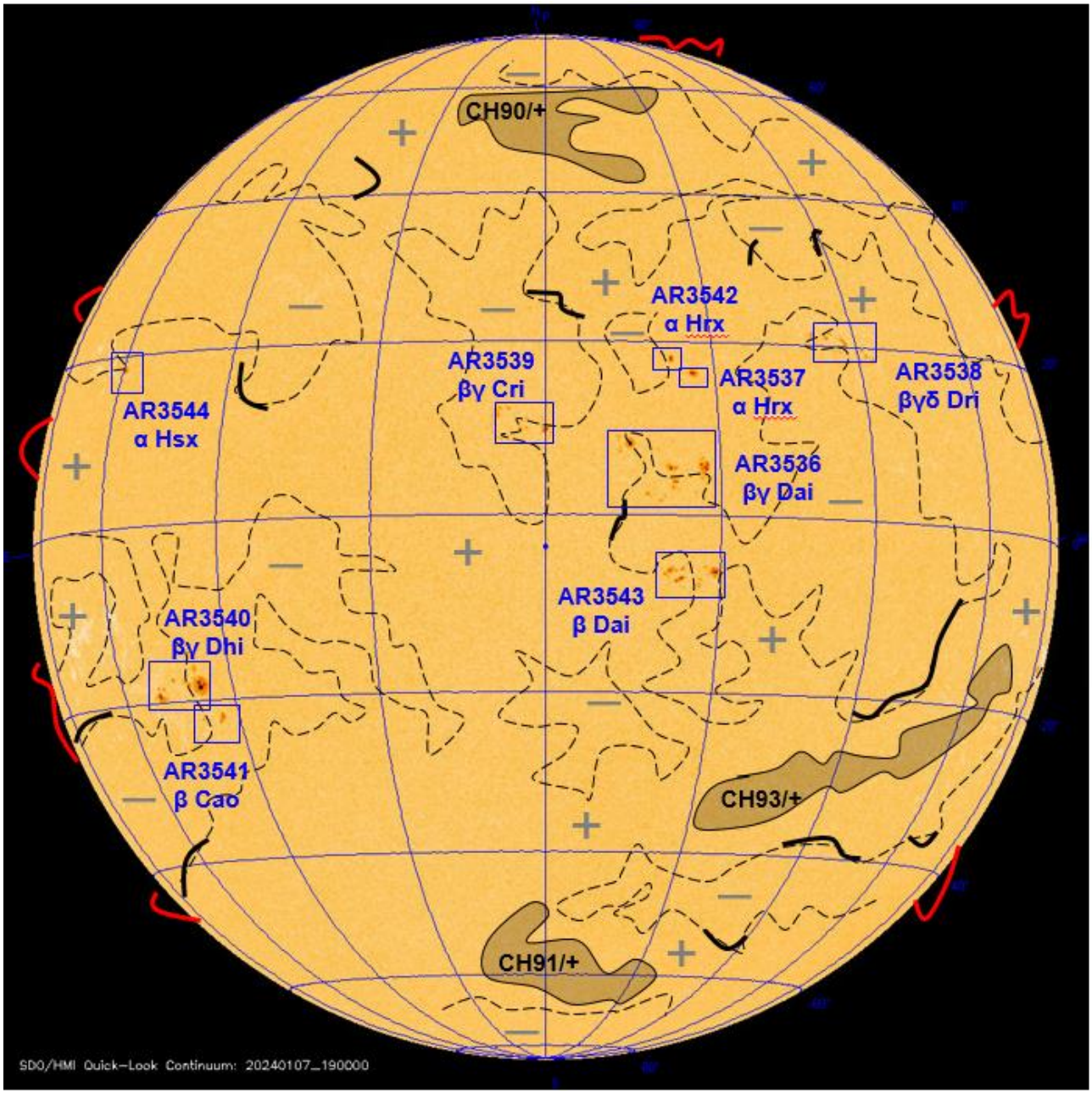
wake of CH89's fast wind and in the possible absence of significant CME effects.

Figure 1. Solar Analysis Valid 07/1900UTC.



Key: Filament ___ , Prominence ___ , Magnetic Field Line - - - , Polarity +/-, Coronal Holes: Grey shaded area CHxx +/-, Sunspot groups 25xx - Mt Wilson α-β-βγ-βγδ and Zurich-McIntosh Axx etc.

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Geomagnetic Storms:

Two CMEs feature in the current forecast. The first originated from the northeastern quadrant on 05 January (but directed southeastward) and is forecast to perhaps glance the Earth either later in the current UTC day (Monday 08 January) or else during the start of day 2 (Tuesday 09 January). Secondly, the filament eruption observed at 06/0620UTC has been provisionally determined to pass 1AU around the turn of the UTC day 09-10 January as a very slight glancing blow. Confidence in this second CME is especially low given that the analysed feature appeared to be better described by a more eastward-directed CME than its departure point on the disc might suggest (i.e. it apparently did not leave purely radially outward).

Earth is currently thought to be transiting a sector of space dominated by a slow solar wind regime. A fast wind from coronal hole 89 may interrupt this in the current UTC day, with speeds in the region of 450km/s possible, although confidence in this forecast is now low for the feature being well overdue - perhaps instead passing below the ecliptic plane. It should be noted that the phi angle has now recently changed to the required positive (away from the Sun), which was a necessary pre-requisite for the fast wind. MOSWOC Enlil has been grossly in error with CH89, bringing it in at least 48 hours early with a magnitude 100-150km/s in excess of expectations, and this is liable to have accelerated inbound CMEs injected into this modelled wind. The corollary of this is that the CMEs are now more likely to arrive later within their allotted error bars (if at all), with accordingly more modest impacts.

Any fast wind is now expected to be muted and short-lived, such that a slow regime ought to resume by the end of 09 January. As the coronal hole high speed stream and first CME are now forecast to affect the Earth around the same time, the CME could serve to enhance any CIR which may mitigate against the otherwise reduced impact for the fast wind being so late, and the peak risk of a Slight Chance of G1 is therefore maintained in the first 24 hours.

The result of the above factors is a falling Slight Chance of G1 throughout the first half of the UTC working week, perhaps Quiet by midweek should the second CME miss.

Geo-Magnetic Storm	**Level**	**Past 24 Hours (Yes/No)**	**Day 1 (00-24 UTC)**	**Day 2 (00-24 UTC)**	**Day 3 (00-24 UTC)**	**Day 4 (00-24 UTC)**
Probability (Exceedance)			**(%)**	**(%)**	**(%)**	**(%)**
Minor or Moderate	**G1 to G2**	No	20	10	5	1
Strong	**G3**	No	1	1	1	1
Severe	**G4**	No	1	1	1	1
Extreme	**G5**	No	1	1	1	1

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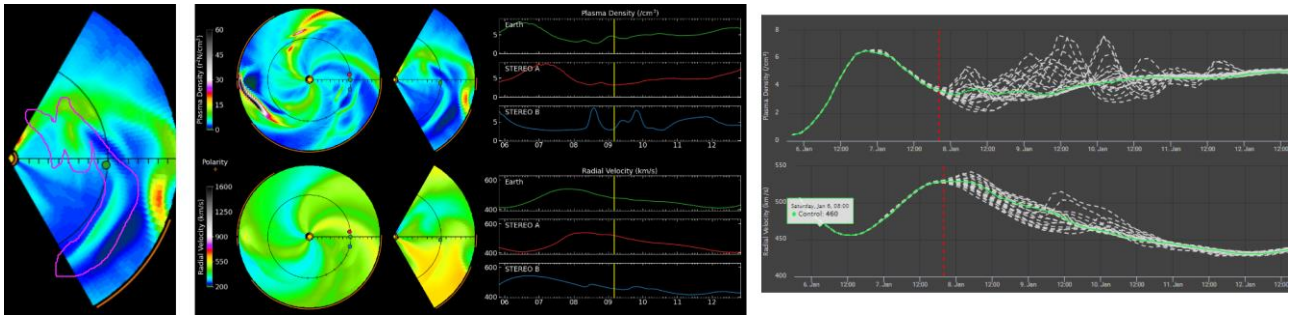
Geomagnetic Activity - Earthbound Coronal Mass Ejections

Date/time 21.5R (UTC)	Halo: Full or Partial	Source	Source Location	Estimated Speed	Estimated Arrival Time	Comments
05/1746	Partial?	Filament	NE	393	At or after 08/1800UTC	Low confidence, but most likely to affect Earth.
06/2014	Partial?	Filament	E central	480	At or after 10/0001 UTC, more likely a miss	Tentative analysis, mainly S and E of Sun-Earth line.

Figure 2: Latest MOSWOC Enlil run (badge time 07/2000UTC), showing side slice and up to three highlighted CMEs of near miss or glancing incidence – respectively the 05 January SE filament CME (outermost), 06 January W central filament CME and 07 January NW filament CME. The effect on the deterministic run is minimal or nil in all cases, however the ensemble becomes very chaotic after the first 12 hours of the coming 96. This complexity can nevertheless be distilled into slight and reducing geomagentic impacts through the first half of the coming UTC working week. An unperturbed wind should resume from after midweek as things stand.



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Radio Blackouts - X-Ray Flares:

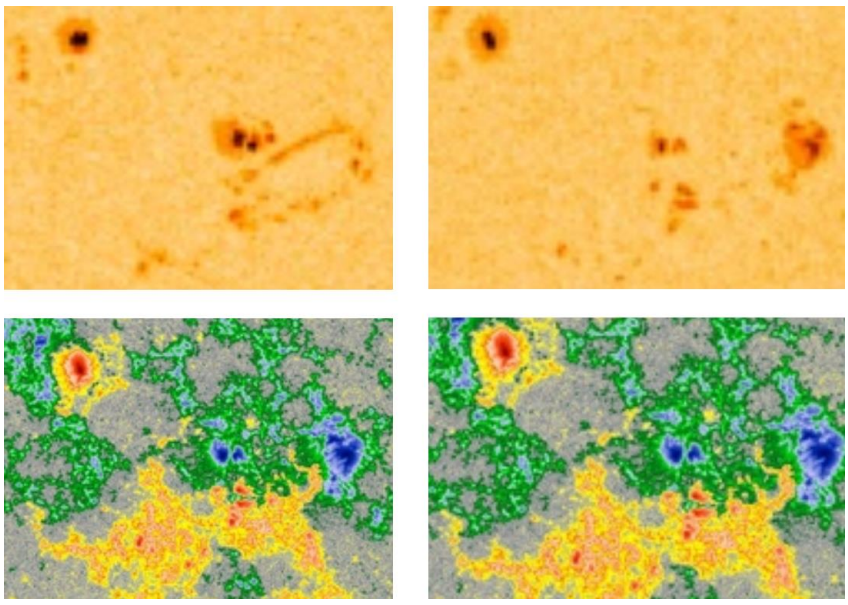
The daily risk of X-ray flares is currently difficult to ascertain. The raw values for M-class flares for the disc are near 50%, however this is based on Zurich classifications, and the unaccounted for Mt Wilson groups have been more complex than average in recent days (but are now simplifying). Coupled with other factors such as rapid growth in some groups (not part of the classification schemes) and the east-west magnetic neutral line and brief sigmoid flux in AR3536 near centre-disc, all amount to a complex forecast.

Only AR3538 leaves the disc at the very end of the current four-day period. Regarding arrivals, the far southeast limb is now showing a possible returning region (perhaps Ex-AR3532?), and far-side soundings and returning Carringtons perhaps suggest further regions are due with a steady cadence through the period.

All considered, there is a very slight ramping of the risk of M-class from a Chance to perhaps become Likely, moderating slightly to end the four days.

X Ray Flares	Level	Past 24 Hours (Yes/No)	Day 1 (00-24 UTC)	Day 2 (00-24 UTC)	Day 3 (00-24 UTC)	Day 4 (00-24 UTC)
Probability			(%)	(%)	(%)	(%)
Active	R1-R2 M Class	No	50	55	60	55
Very Active	R3 to R5 X Class	No	5	5	5	5

Figure 3: Four-up of AR3536 near centre disc to start (left) and end (right) the 24 hours. Views show HMIIF (top) and HMIBC (bottom) – of particular note is the ring-like structure of flux in the leader to tsart the period in HMIIF, which later went through a sigmoidal stage before migrating west and consolidating into a main penumbral spot. Note also the east-west oreintation of the magnetic netural line – giving a propensity toward shear from differential rotation.



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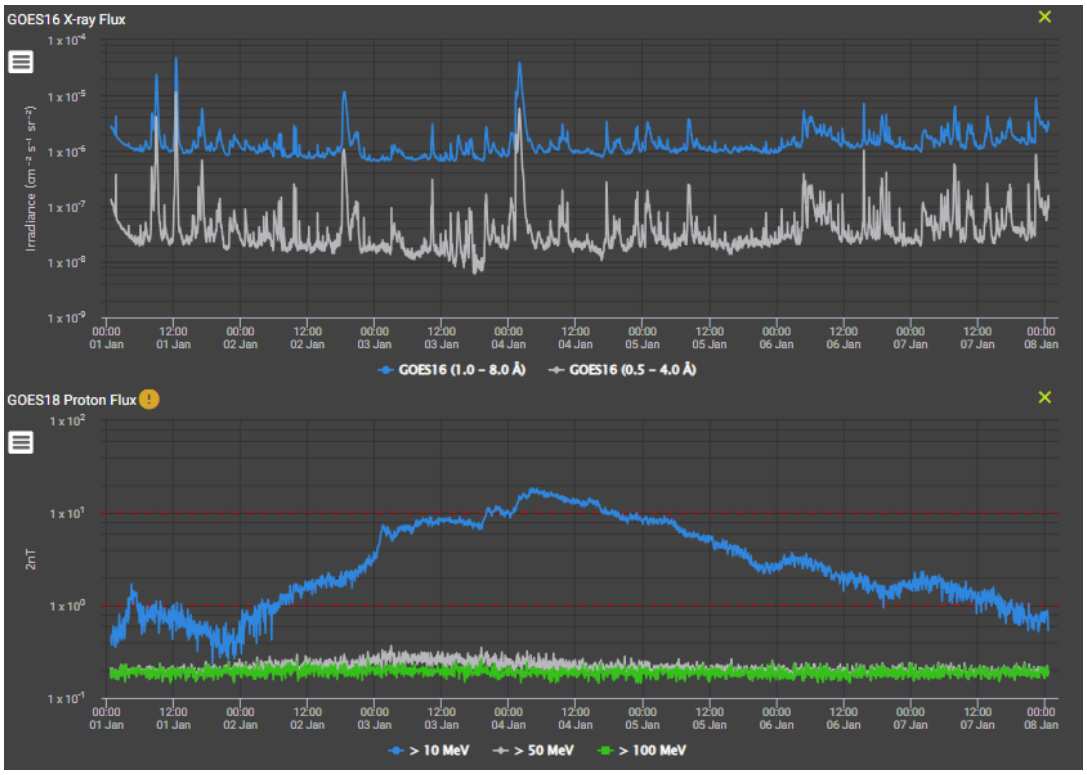
Solar Radiation Storms - (High Energy Protons):

GOES16 high energy (greater than 10MeV) proton flux remains very slightly above resting background levels in the wake of the possible generating X-class flare that greeted the New Year. The soft spectrum and very gradual rise and fall certainly suggest a far-side or east limb source. Flux levels will most likely continue their very gradual relaxing trend in the next day or so, however inbound CMEs may compress some of the inbound trickle of protons into a larger pulse, which may still lead to S1 risks a little above that suggested by the raw disc probabilities (which remain nearer 10% daily risk).

In the absence of further proton-rich flares in prone locations, levels may be allowed to relax back to resting background before the middle of the coming UTC working week, with the S1 risk finally relaxing back to the raw disc by midweek UTC.

Radiation Storms Probability (Exceedance)	Level (cm^{-2} sr^{-1} s^{-1})	Past 24 Hours (Yes/No)	Day 1 (00-24 UTC) (%)	Day 2 (00-24 UTC) (%)	Day 3 (00-24 UTC) (%)	Day 4 (00-24 UTC) (%)
Active	**≥ S1**	No	15	15	10	10
Very Active	**≥ S3 ***	No	1	1	1	1
* S3 ≥ 10 MeV ≥ 1000 pfu and / or ≥ 50 MeV ≥ 10 pfu. (pfu = $cm^{-2}sr^{-1}s^{-1}$)						

Figure 4: Past week in GOES16 X-ray flux (top) and resultant GOES18 proton flux (bottom). 10MeV protons at GEO have now nearly returned to their resting background, having breached S1 late on 03 January in the wake of large eastern solar hemisphere flares (hence the damped response).



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High Energy Electrons Event (≥ 2MeV):

The current subdued high energy electron flux (greater than 2MeV) - Normal Background at GEO - is expected to continue in the near-term in the now delayed or possibly even absent fast wind enhancement and with the uncertainty tied to inbound CMEs.

Should CH89/+ materialise, its implied slower emanating speed should mean that the risks of nearing Active 24-hour integrated fluence are now very low. So, while there may be an eventual slight increase observed, CH89's tardiness and persistence suggest that there is now a reduced Slight Chance of exceedence from around midweek. This may be further dented by any second inbound CME, and the presence of this and the earlier transient are likely to render confidence in MOSWOC REFM relatively low throughout, even if its suggested trend happens to be the favoured scenario - as now.

GEO Electron Environment	**Level (cm^{-2} sr^{-1} day^{-1})**	**Past 24 Hours (Yes/No)**	**Day 1 (00-24 UTC)**	**Day 2 (00-24 UTC)**	**Day 3 (00-24 UTC)**	**Day 4 (00-24 UTC)**
Probability (Exceedance)			**(%)**	**(%)**	**(%)**	**(%)**
Active	**≥ 2 MeV ≥ $1x10^{8}$**	No	1	1	5	5
Very Active	**≥ 2 MeV ≥ $1x10^{9}$**	No	1	1	1	1

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